LANDSAT 7 SYSTEM

Image Assessment System Operations Concept

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SECTION 1
INTRODUCTION

The Landsat-7 satellite mission is a joint NASA/NOAA/USGS program which will provide a wide-area multispectral imaging capability serving the global change research, national security, civil, and private sector users. Landsat-7 is scheduled for launch in 1998 with a planned operational life of 5 years. The space vehicle is designed for a 705 km, sun synchronous, earth mapping orbit with a 16 day repeat cycle. The mission payload consists of the Enhanced Thematic Mapper Pluts (ETM+), an improved version of the Landsat 4/5 thematic mapper payloads. ETM+ provides data continuity with the Landsat 4/5 missions while adding a 15m panchromatic band and improved radiometric performance. The Landsat-7 satellite provides payload data to a Landsat Ground Station (LGS) in Sioux Falls, South Dakota and a collection of International Ground Stations (IGS) through a direct wideband downlink capability.

1.1 PURPOSE

This Operations Concept describes the mission and operations concept of the Landsat-7 Image Assessment System (IAS). Its purpose is to provide assistance and guidance for the engineering development, design, integration, and test activities of the IAS, by defining the manner in which operations will be conducted and the role that various system components will play in achieving mission success. The level of depth to which these concepts are described is intended to fully support validation and/or derivation of system operating requirements. These concepts will continue to evolve throughout the development process.

1.2 ELEMENT OVERVIEW

The IAS is a system element located at the the Earth Resources Observation Systems (EROS) Data Center (EDC) in Sioux Falls, South Dakota. As an element of the Ground Data Handling Segment, the IAS is responsible for the off-line assessment of image quality to ensure compliance with the radiometric and geometric requirements of the spacecraft and ETM+ sensor throughout the life of the Landsat-7 mission. Operational activities occur at EDC while less frequent assessments and and calibration certification are the responsibility of the Landsat-7 Project Science Office at the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland.

1.3 DOCUMENT OVERVIEW

Section 1, Introduction, identifies this document, its contents, and provides for a system overview.

Section 2, Applicable Documents, lists all pertinent documents or documents referred to within this Operations Concept.

Section 3 provides the Operations Concept for the IAS. Six major functions are described.

Section 3.1, Level 1 Processor, describes the functionality required by IAS to convert level 0R data to higher correction levels.

Section 3.2, Geometric Calibration, describes the procedures performed by IAS to maintain instrument and satellite calibration.

Section 3.3, Radiometric Calibration, describes the procedures performed by IAS to ensure that absolute radiometric calibration of ETM+ data is maintained.

Section 3.4, Performance Evaluation, describes the procedures performed by IAS to measure the geometric, radiometric, and image quality performance of the ETM+ sensor and satellite.

Section 3.5, Process Control & Data Management, describes the functionality required to launch processes and collect, disseminate, and store all data, analysis results, processing parameters and assessment reports.

Section 3.6, Manage IAS, describes the day-to-day activities that ensure the assessment and calibration schedule formulated by the Landsat-7 Quality Assurance Team (LSQAT) is successfully implemented.

Section 4.0, Operational Scenarios, steps through the chain of events required to calibrate the sensor and satellite, evaluate the sensor's performance, and adequately respond to data anomolies.

Section 5.0, Notes, contains a glossary and acronym list to assist the reader in understanding the language common to the Landsat-7 system and the IAS in particular.

SECTION 2
APPLICABLE DOCUMENTS

2.1 GOVERNMENT DOCUMENTS

The following Government documents complement the concept descriptions provided here, and in some cases expand on specific aspects of system operation.

1. National Aeronautics and Space Administration (NASA) Earth Science Mission Operations Landsat 7 System Specification, GSFC, 430-L-000-2-0, August 1994. **(Baselined version issue date: October 28, 1994)**

2. Landsat 7 System and Operations Concept, October 13, 1994.

3. Landsat 7 Program Coordinate System Standard, GSFC, *

4. Space Segment Calibration Plan, Martin Marietta Astro Space, CDRL No. A104, August 26, 1994.

5. Radiometric Calibration and Coorection Plan for the Enhanced Thematic Mapper Plus (ETM+), Martin Marietta Astro Space, PIR No. U-S/C-L7-0424-MSE, November 22, 1994.

6. Landsat 7 MOC to IAS Interface Control Document.

7. Landsat 7 IAS to LPS Interface Control Document.

8. Interface Requirements Document Between EOSDIS Core System (ECS) and the Landsat 7 System, Hughes Applied Information Systems, #194-219-SE1-003, working draft, June 1994.

2.2 NON-GOVERNMENT DOCUMENTS

The following non-Government documents complement the concept descriptions provided here, and in some cases expand on specific aspects of system operation.

CCSDS 700.0-G-2 Advanced Orbiting Systems, Networks and Data Links: Summary of Concepts, Rationale and Performance

CCSDS 701.0-B-1 Advanced Orbiting Systems, Networks and Data Links: Architectural Specifications

2.3 PROGRAM DOCUMENTS

The following program documents complement the concept descriptions provided here, and in some cases expand on specific aspects of system operation.

(TBD)

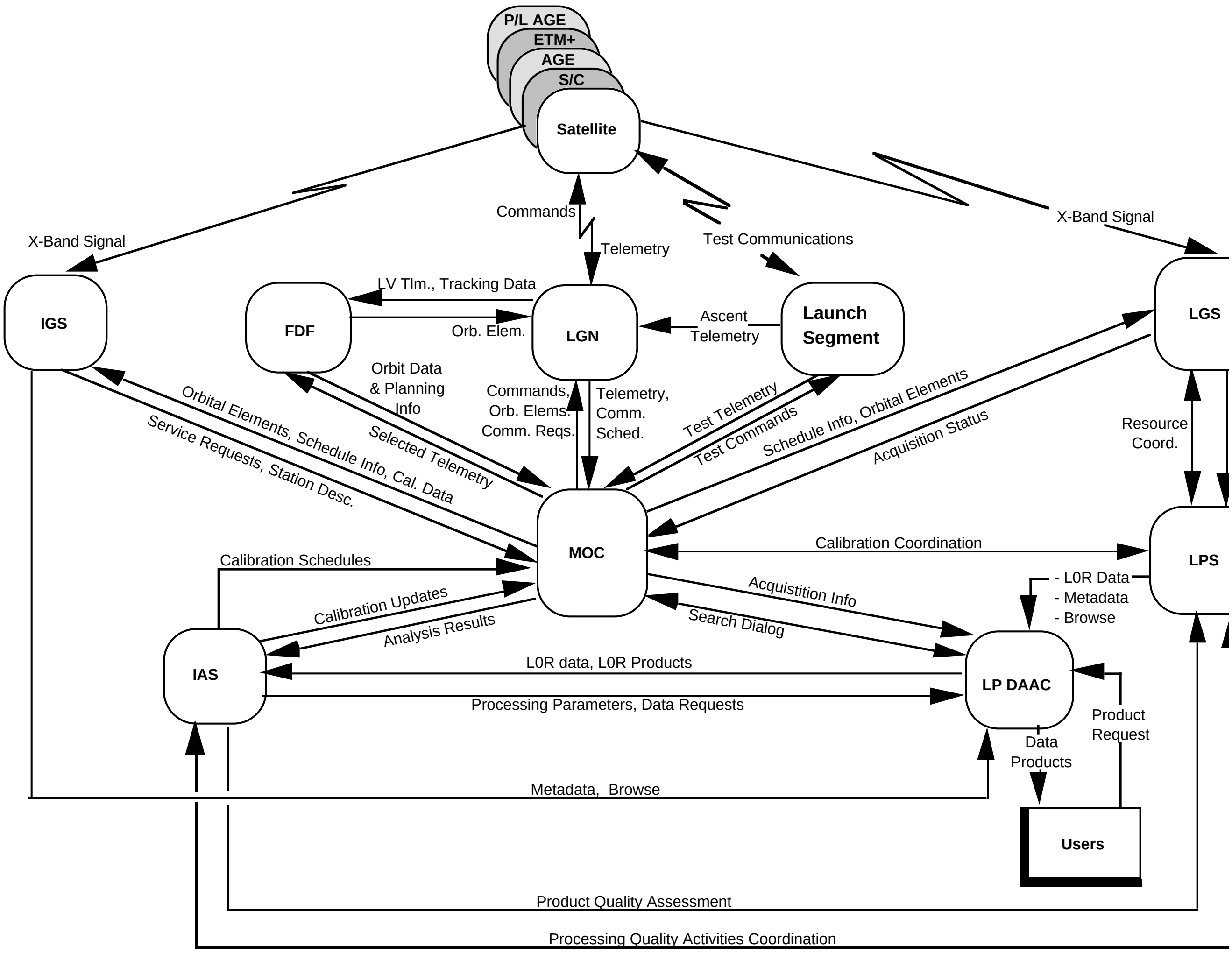

Figure 3.1-1 Landsat 7 System

SECTION 3
OPERATIONAL SYSTEM

3.1 IAS OPERATIONAL OVERVIEW

The Landsat 7 space/ground system as described in the Landsat 7 System Operations Concept is depicted in Figure 3.1-1. This figure illustrates the Landsat 7 operational system elements and interfaces.

The IAS receives Level 0R data and products from the Land Processes Distributed Active Archive Center (LPDAAC). These data include ancillary information such as browse and metadata. The IAS assesses these data in raw form, or processes the data to Level 1R and 1G and assessed as Level 1 products. The data are assessed with respect to their geometric and radiometric qualities. Data examinations consist of individual and long term trending analyses. Data quality assessments and reports are sent to the LPS, LPDAAC, Mission Operations Center (MOC), and the Mission Management Office (MMO). Processing parameter updates are sent to the LPS, LPDAAC, and MOC. In addition to its assessment functions, the IAS is also responsible for the radiometric and geometric calibration of the Landsat 7 satellite and ETM+. Initial calibration data are received pre-launch from the ETM+ contractor and the Space Segment Satellite. Calibration updates are passed by the IAS directly to the LPDAAC (and to the IGSs through the MOC). Anomalies are reported to the MOC and the LPS.

3.2 IMAGE ASSESSMENT SYSTEM OPERATIONS

Figure 3.2-1 depicts the data flow diagram for IAS operations. Six major functions are performed by the IAS. These include Level 1 Processing, Geometric Calibration, Radiometric Calibration, Performance Evaluation, Data Archive & Distribution, and Manage IAS. The following sections describe these functions in detail.

3.2.1 Level 1 Processing

The Level 1 Processing function generates Level 1R and 1G images and data. The 1R image is a radiometrically corrected image. The 1G images include systematic, precision, and terrain corrected imagess. The Level 1 Processing function will have the capability to generate data with a variety of projections using any arbitrary ellipsoid.

Figure 3.2.1-1 depicts the the data flow diagram for the Level 1 Processing function. Level 1 Processing receives 0R data and products and metadata from the IAS Control Processes and Manage Data function. Additionally, any pre-launch calibration data are supplied to the Level 1 Processing function from Control Processes and Manage Data. The major sub-functions of Level 1 Processing include Process Attitude/Jitter Data, Perform Radiometric Correction, and Perform Geometric Correction.

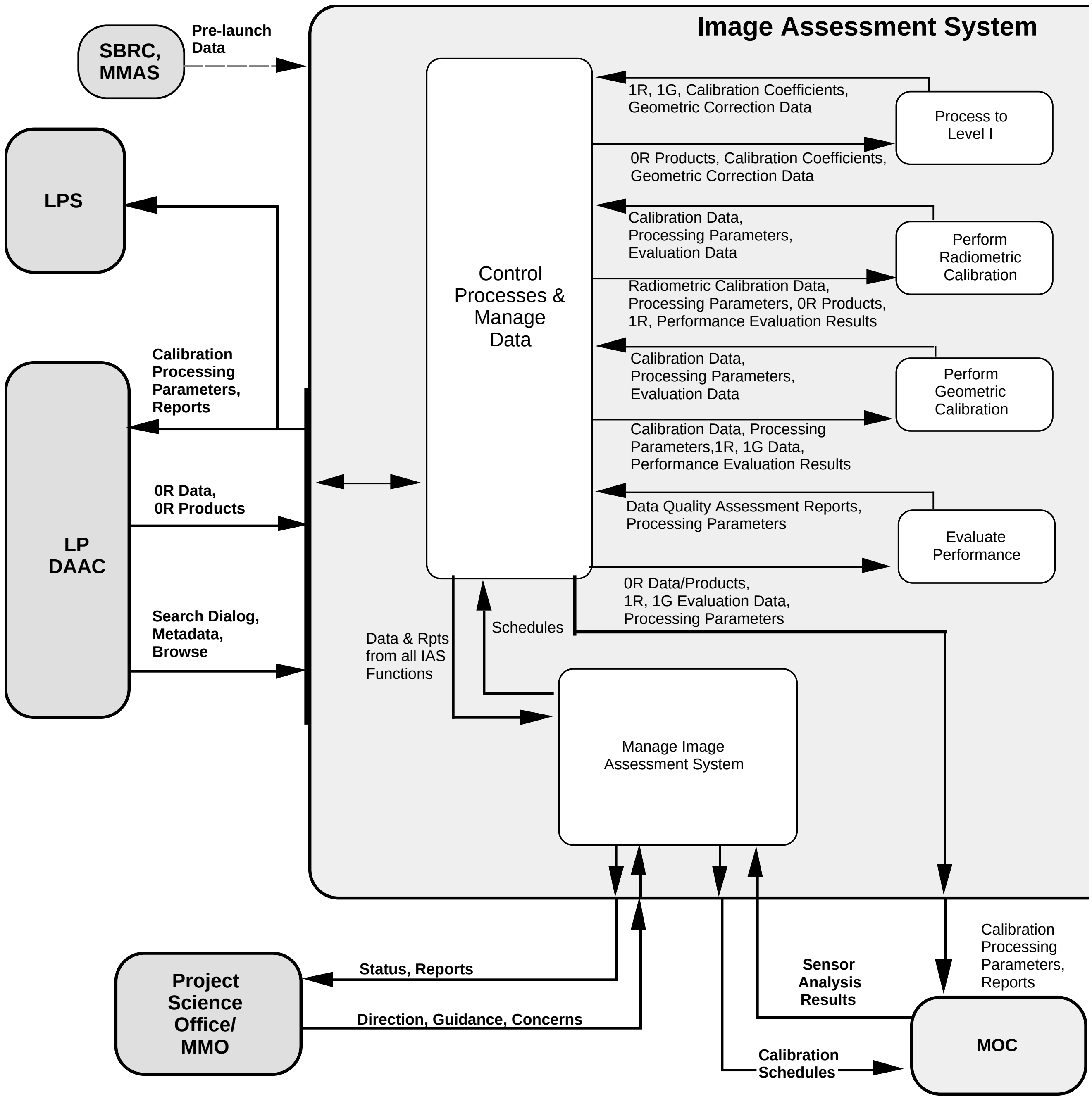

Figure 3.2-1 IAS Data Flow

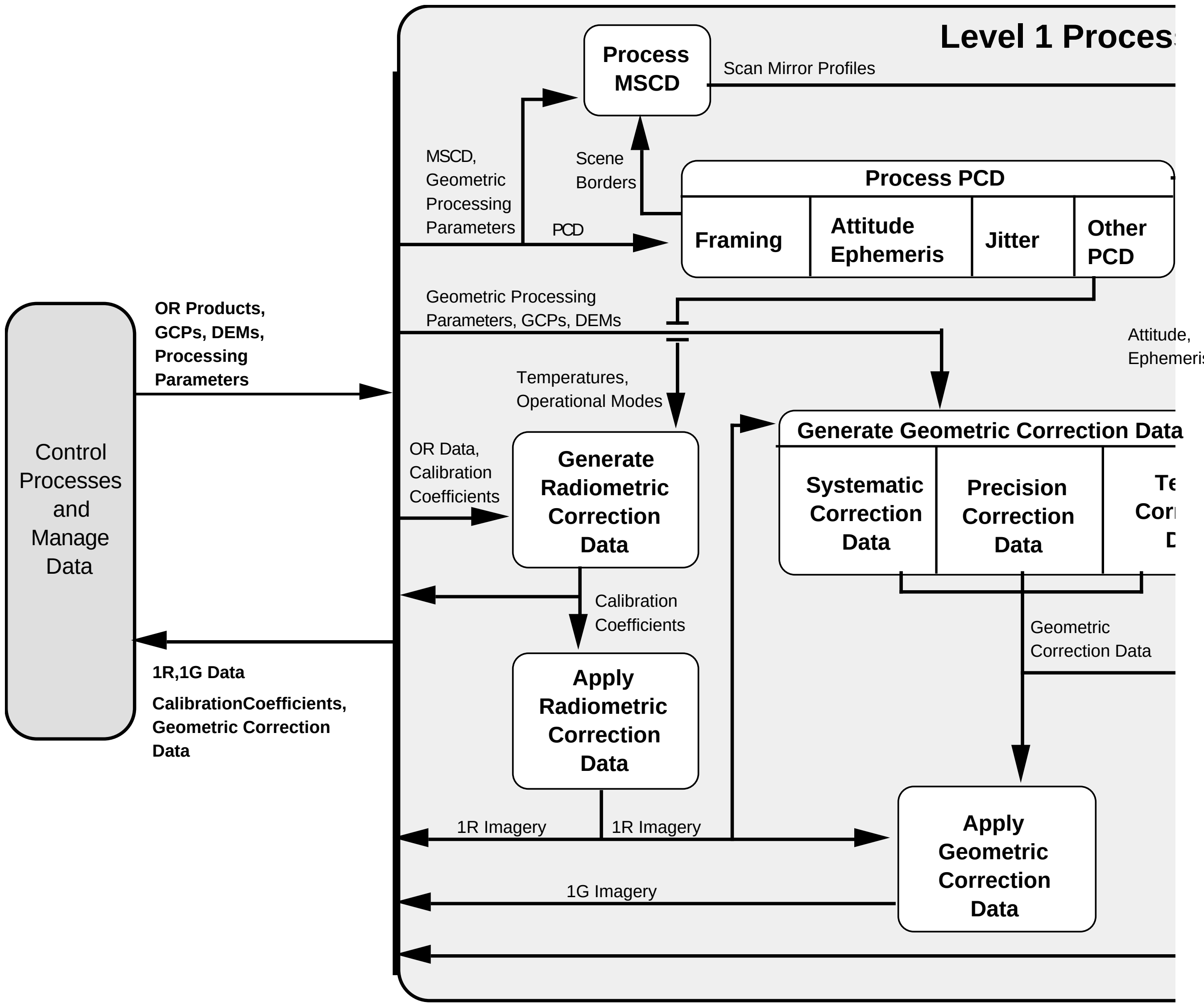

Figure 3.2.1-1 Level 1 Processing Data Flow Diagram

3.2.1.1 Process Payload Correction Data (PCD)

The Process PCD sub-function is performed for each set of Level 0R data or product received by the Level 1 Processing function. The Process PCD sub-function determines framing for the scene to be processed and passes that information to the Process MSCD sub-function and uses it to limit jitter processing needed for the scene. This sub-function processes the ephemeris and attitude profiles received in the wideband telemetry to produce estimates of the ETM+ sensor's total attitude deviations. Ephemeris processing includes corrections of the on-board clock drift. Jitter data is processed, the results of which are reflected in the attitude and ephemeris output from this sub-function.

The raw telemetry data that are required as input are delivered from Control Processes and Manage Data with the Level 0R data package or product. Additional data provided by Control Processes and Manage Data includes pre-launch calibration data. This pre-launch data includes gyro and angular displacement sensor (ADS) transfer functions, scale factors, and vehicle alignment data. Output profiles of low and high frequency are provided as input to the Generate Geometric Correction Data sub-function. Temperatures and operational modes are extracted from the PCD and used to generate radiometric correction data.

3.2.1.2 Process Mirror Scan Correction Data (MSCD)

The Process MSCD sub-function inputs MSCD and geometric processing parameters from the 0R product from the Control Processes and Manage Data function and scene boundaries, MSCD start time , and operational modes from the Process PCD sub-function. The MSCD consists of scan mirror start times in spacecraft time, the mid-scan intervals (FHSERR and SHSERR), and scan direction for each scan in the subinterval. The geometric processing parameters contain the scan mirror profile coefficients. This sub-function estimates the scan mirror deviations from linear and outputs the deviations on the jitter sample grid for the requested scene.

3.2.1.3 Generate Radiometric Correction Data

The Generate Radiometric Correction Data process extracts radiometric calibration data from the 0R image, shutter, and payload correction data, and with the output resultant from this function and parameter files from the Control Processes and Manage Data, computes radiometric correction factors for each ETM+ channel in each band. For the relective bands, dark shutter data are analyzed to produce the bias estimates. The gain estimates for the reflective bands will be extracted from the Generate Radiometric Correction Data function output and/or computed from the extracted Internal Calibrator pulse data. For the thermal band, black shutter plate data and shutter black body data, in conjunction with a near-field model, are used to produce the gain and bias estimates. Outputs of the process are these radiometric correction factors (gains and biases), to be utilized in the Apply Correction Data function, and diagnostic parameters, e.g. calibration pulse and background levels, for the Control Processes and Manage Data function.

3.2.1.4 Apply Radiometric Correction Data

The Apply Correction Data process uses the radiometric correction coefficients from the Generate Radiometric Correction Data process to produce Level 1R data. Each detector sample from the ETM+ image scans will be rescaled to a common dynamic range for all detectors in a band via the correction curve equation. The rescaled data are directly transferable to absolute radiometric units. Level 1R data are provided to Control Processes and Manage Data.

3.2.1.5 Generate Geometric Correction Data

The Generate Geometric Correction Data sub-function is performed in order to create 1G image data. Input to the sub-function is attitude, ephemeris, jitter, scan mirror profiles and geometric parameters. Level 1R image data is used to generate precision correction data. Pre-launch calibration data is required to initialize the geometric correction processing parameter database for geometric data processing prior to the initial series of system calibration activities. Nominally, the database will be updated and the latest correction processing parameters will be used. Output from the sub-function is a set of geometric correction data. Additionally, the geometric correction data are an input to the Apply Geometric Correction Data sub-function where the Level 1G image is generated. Geometric correction data allows a user to associate image data with a defined ellipsoid and map projection. Three types of geometric correction data can be produced: systematic, precision, and terrain. These three processes are described below.

3.2.1.5.1 Generate Systematic Correction Data

The Generate Systematic Correction Data process is responsible for producing an image to ground mapping data set that uses ephemeris from the PCD, or definitive ephemeris data from the Flight Dynamics Facility (FDF) if available, and attitude profiles from the Process PCD sub-function described above. This mapping data set and associated ancillary data are collectively known as systematic correction data and is the primary output of the process. Accuracy of the correction data are primarily driven by the accuracy of the input data (attitude, ephemeris) and the current calibration data (alignment, field angles, detector delays, scan profiles), but excludes effects of topographic variation. The earth model and map projection utilized are operator selectable.

3.2.1.5.2 Generate Precision Correction Data

The Generate Precision Correction Data process is responsible for producing an image to ground mapping data set that utilizes the same data used by systematic correction described above, as well as ground control point information. The ground control point information provides the capability to remove large bias and slowly varying errors in the supporting geometric input data. The accuracy of the precision correction data are driven therefore by the accuracy and amount of ground control point information and the variability of the systematic error sources. The earth model and map projection utilized are operator selectable, however, the ground control point coordinates must be defined in the earth model coordinate system or be able to be transformed into it.

3.2.1.5.3 Generate Terrain Correction Data

The Generate Terrain Correction Data process is responsible for producing an image to ground mapping data set that utilizes the same data used by the systematic and precision correction described above, as well as ground terrain information obtained from a terrain model (Examples of applicable elevation data sets are USGS digital elevation models (DEMs) or DMA Digital Terrain Elevation Data (DTED I)). The terrain data provides height above the ellipsoid where the mono earth intersection calculation is performed. Accuracy of the terrain correction data are primarily driven by the accuracy of the input data (attitude, ephemeris, and elevation) and the current calibration data (alignment, field angles, detector delays, scan profiles). The earth model and map projection utilized is operator selectable.

3.2.1.6 Apply Geometric Correction Data

The Apply Geometric Correction Data sub-function is responsible for producing a Level 1G image utilizing the Level 1R data, received from the Apply Radiometric Correction Data sub-function, and geometric correction data, received from the Generate Geometric Correction Data sub-function, as input. The process by which the geometric correction data are used to produce the Level 1G image is known as resampling. The Level 1G image is a regular output grid of pixel intensities for a given WRS path and row in an operator selected map projection coordinate system. Resampling removes the misalignments, skewing, overlap, and underlap that may be present in the radiometrically corrected ETM+ image data. The output of the Apply Geometric Correction Data sub-function is a Level 1G image and accompanying support data, which are provided to Control Processes and Manage Data function .

3.2.2 Geometric Calibration

The Geometric Calibration function is responsible for providing calibration data for the improvement of geometric quality and accuracy of the Landsat 7 imagery. Specifically, this function will provide periodic updates to the sensor line of sight alignment angles, the band to band and within band detector offsets, the detector delays, and scan mirror and scan line corrector mirror profiles. These calibration items support the geodetic accuracy, band-band registration accuracy, and the linear feature continuity in the Landsat 7 imagery.

Figure 3.2.2-1 depicts the the data flow diagram for the Geometric Calibration function. Geometric Calibration receives pre-launch geometric processing parameters, Level 1R and 1G data from Control Processes and Manage Data function. The Geometric Calibration function provides geometric processing parameter updates (in the form of band to band and within band detector field angle offsets, sensor alignment angles, detector delays and mirror profiles), reports, and evaluation data to the Control Processes and Manage Data function. The major sub-functions of Geometric Calibration include Perform Band to Band Registration Calibration, Perform Sensor Alignment, Perform Along Scan Calibration, Perform Across Scan Calibration, and Provide Calibration Updates. These sub-functions are described below.

3.2.2.1 Perform Band to Band Registration Calibration

The Perform Band to band Registration Calibration function is performed once during in-orbit check out (IOC), and at 90 day intervals thereafter throughout the mission life. The purpose of this sub-function is to calibrate the registration of each imaging band to each other band. This is accomplished via a calibration technique of identifying and mensurating common feature points in each band, determining their relative location in image space, computing the misregistration residuals, and minimizing those residuals via a weighted least squares estimation technique. Perform Band to Band Registration Calibration receives pre-launch geometric processing parameters in the form of band to band detector field angles from the Control Processes and Manage Data function. This pre-launch data will be used for the initial calibration exercise. Subsequent calibration exercises will use the band to band detector field angles from the previous calibration.

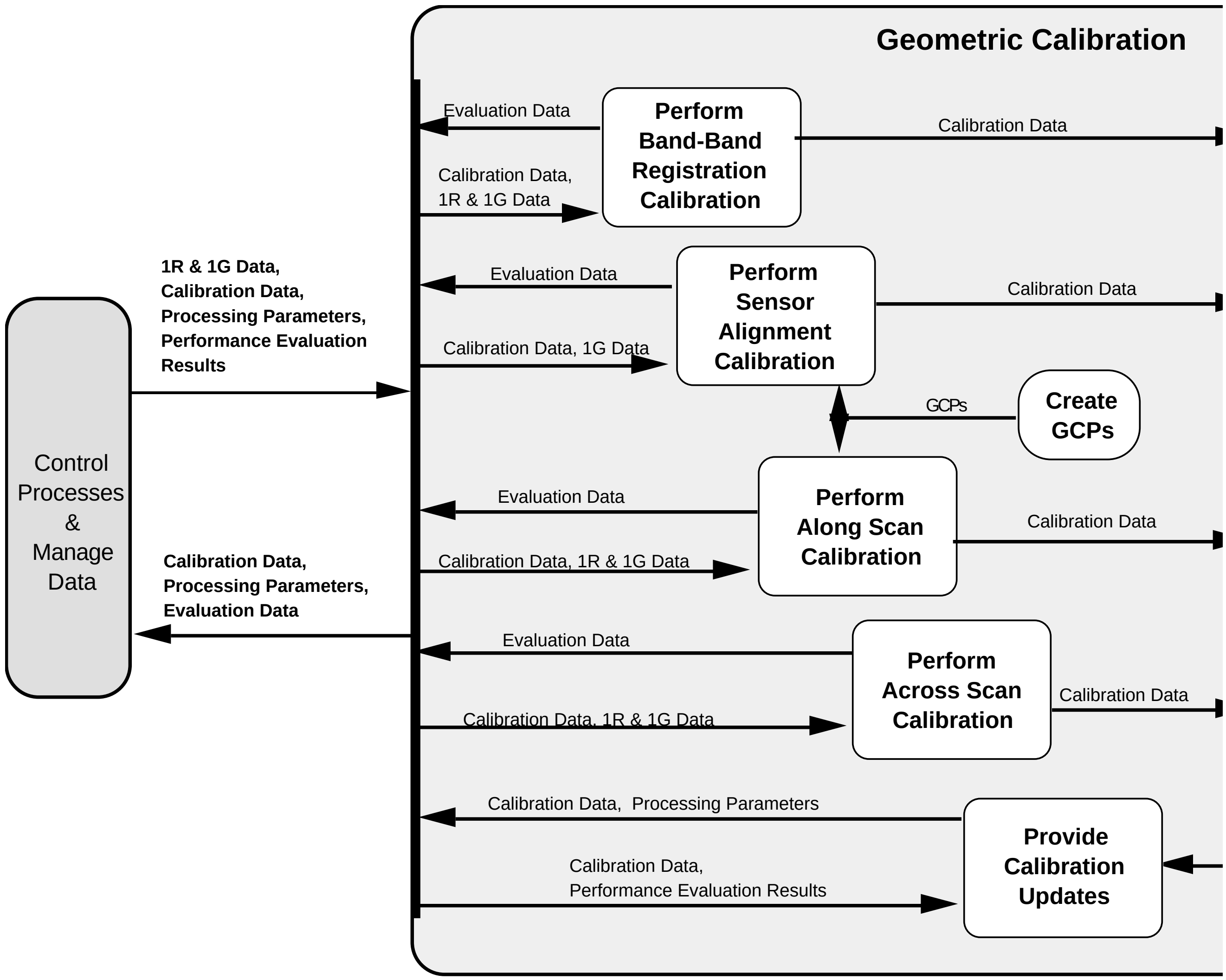

Figure 3.2.2-1 Geometric Calibration Data Flow Diagram

For each calibration exercise, Level 1R and 1G imagery is supplied by Control Processes and Manage Data function to this sub-function. Output from this sub-function shall be in the form of adjusted band to band detector field angles. This data will be forwarded to the Provide Calibration Updates sub-function. Additionally, calibration reports and evaluation data shall be supplied to Control Processes and Manage Data function to be subsequently sent to the LPDAAC. Evaluation data for this sub function shall include registration residuals and covariance data.

3.2.2.2 Perform Sensor Alignment Calibration

The Perform Sensor Alignment Calibration sub-function is performed once during IOC, and at 90 day intervals thereafter throughout the mission life. The purpose of this sub-function is to calibrate the alignment of the ETM+ line-of sight (LOS) to the Navigation Base Reference (NBR). This is accomplished via a calibration technique of identifying and mensurating known ground points in Level 1G imagery over a series of revolutions and computing the difference in image space between expected location and actual location. These differences then represent estimates of total system error. A sufficient number of ground point estimate differences (current estimates are 12 passes of data using PCD ephemeris or 7 passes of FDF supplied ephemeris) are then input to a weighted least squares model designed to estimate the alignment of the LOS to the NBR. Perform Sensor Alignment Calibration receives pre-launch geometric processing parameters in the form of ETM+ LOS - NBR alignment angles from Control Processes and Manage Data. This pre-launch data will be used for the initial calibration exercise. Subsequent calibration exercises will use the the alignment angles from the previous calibration as the best a priori estimate. For each calibration exercise, Level 1G imagery is supplied by the Control Processes and Manage Data function to this sub-function. This imagery shall originally be acquired from the LPDAAC in Level 0R form. It is estimated that up to 3 distinct WRS collection attempts per day will be required initially. This will provide sufficient data, given the uncertainty of weather conditions, to calibrate the alignment angles every 60 days, as well as to estimate any potential alignment variability as a function of time over a descending pass. Output from this sub-function shall be geometric processing parameters in the form of adjusted alignment angles. This data will be forwarded to the Provide Calibration Updates sub-function. Additionally, calibration reports and evaluation data shall be supplied to the Control Processes and Manage Data function to be subsequently sent to the LPDAAC. Evaluation data for this sub-function shall include measurement data and covariance data.

3.2.2.3 Perform Along Scan Calibration

The Perform Along Scan Calibration sub-function is performed once during IOC and at 90 days intervals thereafter throughout the mission life. The purpose of this sub-function is to calibrate the detector offsets, detector delays and the scan mirror profile for the ETM+ forward and reverse scan directions. This calibration will serve to minimize the amount of linear feature discontinuity in the resultant imagery. This will be accomplished through a calibration technique that will employ a digital correlation method to determine detector offsets from predicted positions for each scan direction. Perform Along Scan Calibration receives pre-launch geometric processing parameters in the form of scan mirror profiles, band positions, and detector offsets and delays from the Control Processes and Manage Data function. This pre-launch data will be used for the initial calibration exercise. Subsequent calibration exercises will use the parameters as updated from the previous calibration. For each calibration exercise, Level 1R and 1G imagery is supplied by the Control Processes and Manage Data function. The Level 1G imagery will be produced via a special processing application which applies only the along scan corrections in the resampling process. This will allow for the determination of along scan detector delays. This imagery shall be acquired originally from the LPDAAC in Level 0R form. Output from this sub-function shall be geometric processing parameters in the form of adjusted detector offset and scan mirror profiles for each scan direction. This data will be forwarded to the Provide Calibration Updates sub-function. Additionally, calibration reports and evaluation data shall be supplied to the Control Processes and Manage Data function to be subsequently sent to the LPDAAC. Evaluation data for this sub-function shall include digital correlation fit data.

3.2.2.4 Perform Across Scan Calibration

The Perform Across Scan Calibration sub-function is performed once during IOC and at 90 days intervals thereafter throughout the mission life. The purpose of this sub-function is to calibrate the detector offsets, and the scan line corrector mirror profile for the ETM+ forward and reverse scan direction. This calibration will serve to minimize the amount of misregistration between forward and reverse scans in the resultant imagery. This is accomplished via a calibration technique of identifying and mensurating feature points in adjacent forward and reverse scans, determining their relative location errors, and minimizing those errors by a least-squares technique to relate the errors to detector offsets and the scan line corrector mirror profile updates. Perform Across Scan Calibration receives pre-launch geometric processing parameters in the form of scan line corrector mirror profiles, and detector offsets from the Control Processes and Manage Data function. This pre-launch data will be used for the initial calibration exercise. Subsequent calibration exercises will use the parameters as updated from the previous calibration. For each calibration exercise, Level 1R and 1G imagery is supplied by the Control Processes and Manage Data function. This imagery shall be acquired originally from the LPDAAC in Level 0R form. Output from this sub-function shall be geometric processing parameters in the form of adjusted detector offset and scan line corrector mirror profiles for each scan direction. This data will be forwarded to the Provide Calibration Updates sub-function Additionally, calibration reports and evaluation data shall be supplied to the Control Processes and Manage Data function to be subsequently to the LPDAAC. Evaluation data for this sub-function shall include digital correlation fit data.

3.2.2.5 Provide Calibration Updates

The Provide Calibration Updates sub-function is performed upon receipt of geometric processing parameters from one of four geometric calibration sub-functions (Perform Band to Band Registration Calibration, Perform Sensor Alignment Calibration, Perform Along Scan Calibration, Perform Across Scan Calibration). The purpose of this sub-function is to evaluate the geometric processing parameters provided by the sub-functions versus the current geometric processing parameters to determine if a parameter update is required. This will be accomplished via engineering (and LSQAT) review of the geometric processing parameters and results from performance evaluation performed with the adjusted parameters. Outputs from this sub-function include approved geometric processing parameters updates supplied to the LPDAAC.

3.2.2.6 Generate Ground Control Point (GCP) Chips

The control point extraction sub-function is performed during sensor alignment and mirror scan correction profile calibrations. Its purpose is to identify ground control point locations in ETM+ imagery using an interactive image display workstation and a digitizing table which determines their map coordinate locations. Field control (e.g. Global Positioning System) can also be used for more precise ground control. Image coordinates are measured to sub-pixel accuracy using a cubic convolution zoom. If map control is being used, the X and Y map projection coordinates of each control point measured by the digitizer are stored along with the point's elevation, interpolated from map contours and/or spot elevations by the operator. The projection coordinates are normally converted to geodetic latitude and longitude using the projection and ellipsoid parameters appropriate to the map being digitized.

Each control point's image coordinates are used to extract image "chips"; small image subsets surrounding the control point location. These chips are tested for uniqueness (presence of nearby similar features) and sharpness (degree to which feature is defined in both directions) to evaluate their reliability. Control points which pass these tests are utilized for geometric calibration and stored in a control point library for future use. This ensures that the same control points will be used for multi-date coverage of a common calibration site and results in superior trending analyses and image to image registration.

3.2.3 Radiometric Calibration

The Radiometric Calibration function is responsible for providing calibration data for the improvement of radiometric quality and accuracy of the Landsat 7 imagery. Specifically, this function will provide periodic updates to the gain estimates for each detector of each ETM+ band. These calibration items support the radiometric accuracy requirements of the Landsat 7 imagery.

Figure 3.2.3-1 depicts the data flow diagram for the Radiometric Calibration function. radiometric Calibration receives pre-launch calibration data, 0R data and products, metadata from Control Processes and Manage Data. The Radiometric Calibration function provides calibration updates (in the form of gain estimates), reports, and evaluation data to Control Processes and Manage Data. The major sub-functions of the Radiometric Calibration functions include Process Partial Aperture, Process Full Aperture, Process Ground Look, Perform Optimal Estimation, Perform Equalization, and Provide Calibration Updates.

3.2.3.1 Process Partial Aperture

The Process Partial Aperture sub-function is responsible for processing the image and shutter data associated with each Level 0R image taken daily of the Partial Aperture Solar Calibrator (PASC) views the sun. Input to the sub-function will (1) extract and integrate the detector responses across an area of the solar disk (2) calculate the effective solar radiance at the ETM+ aperture of the same area using the PASC radiance model and (3) extract and integrate the related internal calibrator data. Outputs provided to the Control Processes and Manage Data function will be detector responses, associated PASC radiances, biases and internal clibrator pulse levels as well as evaluation data and calibration reports.

3.2.3.2 Process Full Aperture

The Process Full Aperture sub-function is responsible for processing the image, lamp, and shutter data associated with each 0R image taken of the Full Aperture Solar Calibrator (FASC). Input to the sub-function includes 0R data and products (including vehicle attitude and ephemeris, calibration lamp data and dark shutter data) and pre-launch characterization data (including the spectral bi-directional reflectance distribution function (BRDF) of the FASC panel). The sub-function will (1) extract the

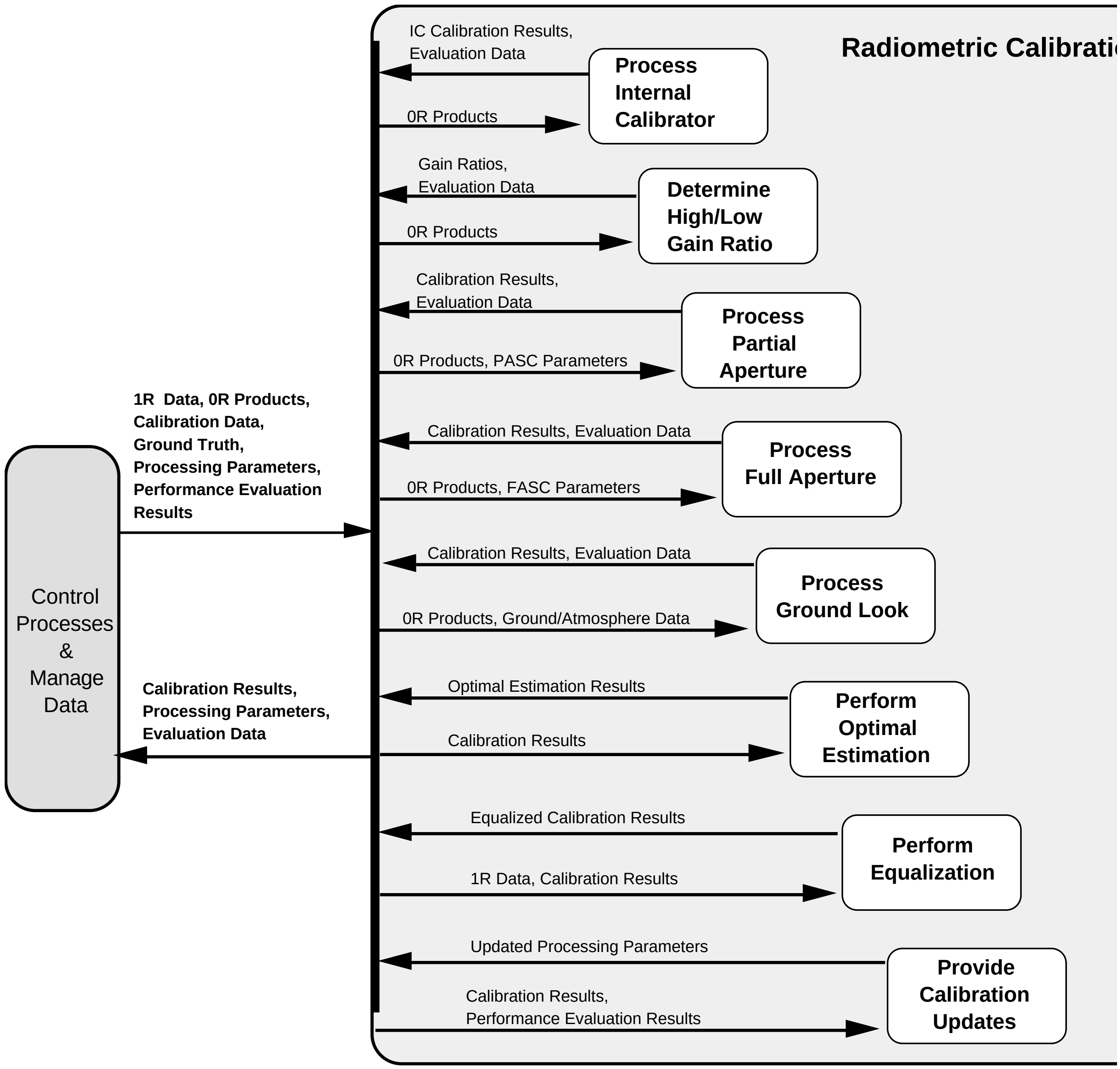

Figure 3.2.2-1 Radiometric Calibration Data Flow Diagram

detector responses to the solar illuminated FASC (2) calculate the reflected radiance from this FASC at times corresponding to the extracted detector responses using the FASC model and (3) extract and integrate the related internal calibrator data. Outputs provided to the Control Processes and Manage Data function will be detector responses, assoicated FASC radiances, biases and internal calibrator pulse levels as well as evaluation and calibration reports.

3.2.3.3 Process Ground Look

The Process Ground Look sub-function is responsible for processing the image and shutter data associated with each 0R image taken of the radiometric ground calibration target(s). Input to the sub-function includes Level 0R data and products and ground measurement data collected at the target site by the ground truth team. Detector response is calculated by methods similar to that used for the PASC and FASC (dark shutter data subtraction). Equivalent at-aperature radiance is computed using an atmospheric model. Detector response and equivalent at-aperature radiance ratios constitute the Ground Look gain estimates. These estimates are the output of the Process Ground Look sub-function and are provided to the Perform Optimal Estimation sub-function. Ground calubration data, evaluation data and reports are provided to Control Processes and Manage Data function fro use in subsequent evaluations within Performance Evaluation function.

3.2.3.4 Perform High/Low Gain Ratio Determination

Associated with each PASC and FASC calibration as well as at other times data will be sequentially collected in high, low, high, low gain modes in order to assess this gain ratio. The sub-function will extract and average detector responses, shutter and lamp data. Ratios of the detector responses and integrated lamp pulses between high and low gain states will be determined and output to the Control Processes and Manage Data function.

3.2.3.5 Perform Optimal Estimation

The Perform Optimal Estimation sub-function is responsible for combining the results from the various calibration sources into a single weighted estimate of the gain of each detector in each band and a single weighted estimate of the internal calibrator radiance for each detector in each band. Inputs to the sub-function include calibration data that Process Partial aperture, Process Full Aperature, Process Ground Look and Determine High/Low Gain Ratios have provided to the Control Processes and Manage Data function (as well as internal calibrator data from other scenes processed to Level 1R). Outputs provided to Control Processes and Manage Data function are gain estimates, internal calibrator radiance estimates, reports and evaluation data.

3.2.3.6 Perform Equalization

The Perform Equalization sub-function is responsible for eliminating residual deviations that may be present in radiometrically corrected imagery after application of the Optimal Estimation gains. Input to the sub-function is a Level 1R data and product package of the most recent FASC image, radiometrically corrected with the Optimal Estimation gains. Detector radiance values are determined over a number of samples and scans, then averaged for each detector. Detector values are then averaged across the band. The Optimal Estimation gains are equalized using this information. The modified detector gain estimates are then provided to the Provide Calibration Updates sub-function.

3.2.3.7 Provide Calibration Updates

The Provide Calibration Updates sub-function is performed upon receipt of calibration data from the Perform Equalization sub-function. The purpose of this sub-function is to evaluate the calibration data provided by the sub-functions versus the current calibration parameters to determine if a calibration parameter update is required. This will be accomplished via engineering review of the calibration data and results from performance evaluation performed with the adjusted parameters. Review of the calibration updates take place within the research element of IAS at GSFC. Outputs from this sub-function include approved calibration updates supplied to Control Processes and Manage Data to be sent to the LPDAAC.

3.2.4 Performance Evaluation

The Performance Evaluation function is responsible for reviewing and assessing the performance of the Landsat 7 imagery and support data with respect to radiometric and geometric quality and accuracy. This function evaluates 0R data and products, and 1R and 1G data , and generates data quality assessments and reports, as well as generating recommendations for modifications to correction algorithms and/or image processing parameters. Performance Evaluation will play a key role in the detection and resolution of performance anomalies, provide periodic baselines of system performance measures, and monitor long term system performance via trend analyses. Level 0R and produect, 1R, and 1G data, metadata, and evaluation data from the Level 1 Processing, Perform Radiometric Calibration, and Perform Geometric Calibration. Figure 3.2.4-1 presents the data flow diagram. Numerous sub-functions comprise the Performance Evaluation function. They are described below.

3.2.4.1 Assess Detector Operability

The Assess Detector Operability sub-function is responsible for identifying ETM+ detectors that exhibit characteristics indicative of inoperability. Level OR data and products are analyzed for the presence of detector performance that demonstrates non-responsive output levels to varying input radiance. Upon identification of a potentially inoperable detector, additional analysis may be performed to determine the time of failure or to characterize the nature of the detector's anomalous performance. Assessment data are provided to the Perform Trend Analysis and Generate Reports sub-functions. Assess Detector is performed nominally every 90 days (TBR) or as needed in support of anomaly resolution.

3.2.4.2 Evaluate Modulation Transfer Function (MTF)

The Evaluate MTF sub-function provides a numerical evaluation of the spatial frequency response of Landsat 7 image data. Evaluation is performed on Level 1R and 1G images containing ground features conducive to MTF determination. These include features such as bridges, highways, or other features with long, high contrast straight edges. Use of both Level 1R and 1G images will allow for an evaluation of the impact of the geometric image processing on the MTF. The MTF is generated for each detector and step response and square wave response is calculated. Assessment data are provided to the Perform Trend Analysis and Generate Reports sub-functions. Evaluate MTF is performed nominally every 6 months or as needed in support of anomaly resolution.

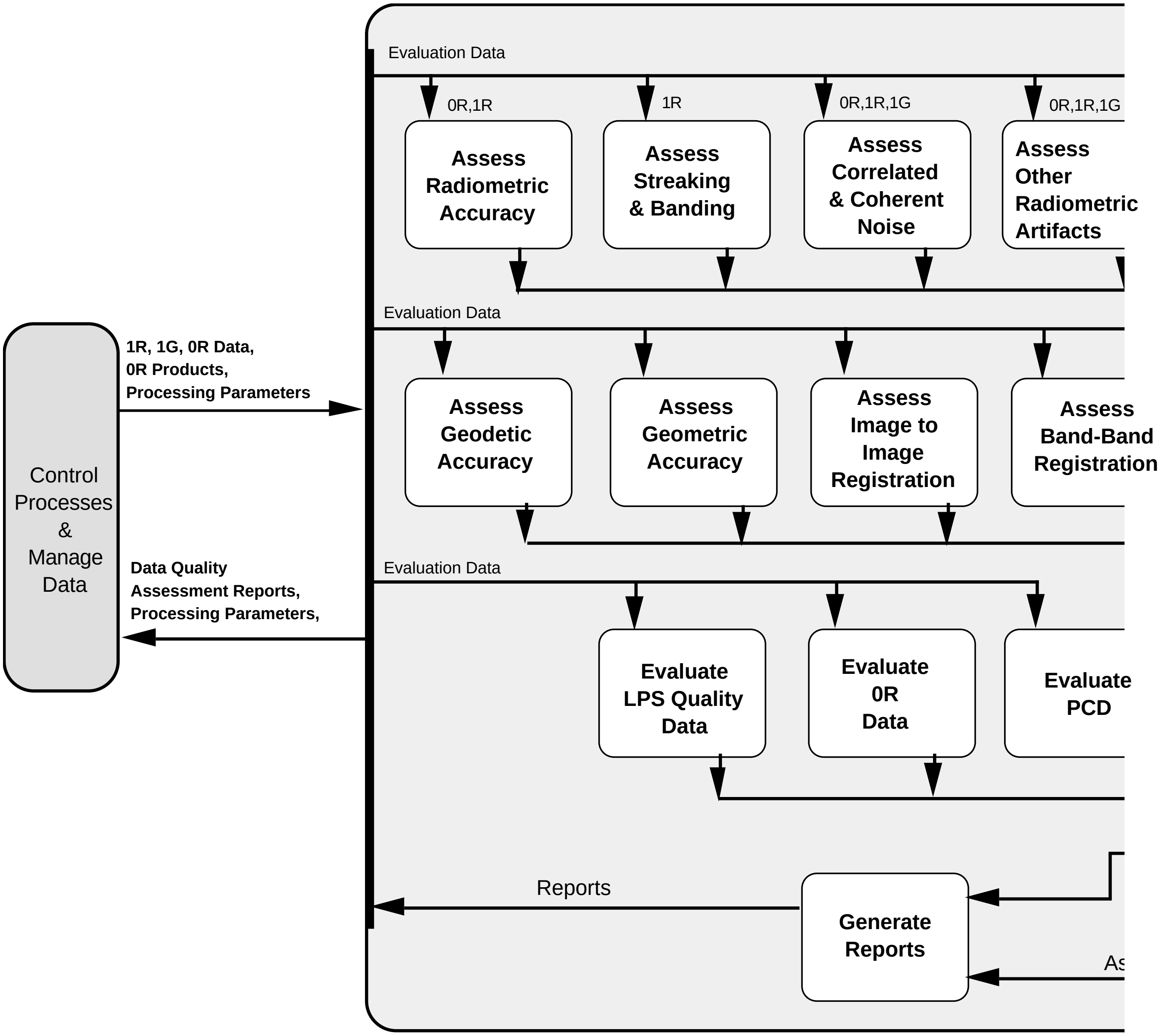

Figure 3.2.4-1 Evaluate Performance Data Flow Diagram

3.2.4.3 Assess Radiometric Accuracy

The Assess Radiometric Accuracy sub-function is responsible for analyzing the stability of the absolute and relative radiometric calibration of the ETM+. Output from the Radiometric Calibration function and level 1R images will be used by the sub-function. The variation in the absolute calibration will be assessed by comparing a new scene of a radiometric calibration source (e.g. FASC, GLC, PASC) to which the current calibration has been applied (by level 1R processing) to the radiance of the scene computed by the radiometric calibration function using only that scene. The variation in the relative calibration will be assessed by computing band ratios of the level 1R data of calibration sources. Assessment data are provided to the Perform Trend Analysis and Generate Reports sub-fucntions. Assess Radiometric Accuracy is performed nominally every 90 days or as needed in support of anomaly resolution.

3.2.4.4 Assess Streaking & Banding

The Assess Streaking & Banding sub-function provides a numerical evaluation of streaking and banding in the Level 1R image. Streaking is computed at the detector level and represents a measure of the variability detector to detector within a band. Banding is computed at the scan level and represents a measure of the variability scan to scan for each band. Assessment data are provided to the Perform trend Analysis and Generate Reports sub-functions. Assess Streaking & Banding is performed nominally every 90 days (TBR) or as needed in support of anomaly resolution.

3.2.4.5 Assess Correlated & Coherent Noise

The Assess Correlated & Coherent Noise sub-function analyzes the noise levels in the Level 1R and 1G images. Correlated Noise values are computed using a two-dimensional autocorrelation function. Coherent noise levels are determined via histogram analysis. Assessment data is provided to the Perform trend Analysis and Generate Reports sub-functions. Assess Correlated & Coherent Noise is performed nominally every 90 days (TBR) or as needed in support of anomaly resolution.

3.2.4.6 Assess Signal to Noise Ratio (SNR)

The Assess SNR sub-function computes the signal to noise ratio in the Level 1R and 1G images. SNR computation is straightforward (ratio of the arithmetic mean to the standard deviation). Assessment data are provided to the Perform Trend Analysis and Generate Reports sub-functions. Assess SNR is performed nominally every 90 days (TBR) or as needed in support of anomaly resolution.

3.2.4.7 Assess Artifacts

The Assess Artifacts sub-function is responsible for analyzing Level 1R and 1G images for the presence of additional image artifacts. Historical Landsat TM data exhibits additional artifacts such as intermittent detector saturation, scan line droop, and bright target recovery. Assessment of the presence/magnitude of these, or other yet to be observed, artifiact, is performed in this sub-function. Analysis may take various forms, from mathematical evaluation of image data to visual inspection. For scan droop, an analysis of banding levels around the edges of large spatially uniform areas is performed. For bright target recovery, visual examination of imagery is sufficient. New assessment algorithms will be developed for in incorporation here, for analysis of newly discovered artifact types as needed. Assessment data are provided to the Perform trend

Analysis and Generate Reports sub-functions. Assess Artifacts is performed nominally every 90 days (TBR) or as needed in support of anomaly resolution.

3.2.4.8 Assess Geodetic Accuracy

The Assess Geodetic Accuracy sub-function provides a numerical evaluation of the geodetic accuracy of Level 1G images. Assessment is performed on a level 1G image containing geodetically known and accurate ground control points. These points are mensurated and a geodetic latitude, longitude, and height is determined utilizing the geometric correction support data. This measured groundpoint is compared to the known ground location. A significant sample of comparisons are computed and a statistical evaluation point is determined. Assessment data are provided to the Perform Trend Analysis and Generate Reports sub-functions. Assess Geodetic Accuracy is performed nominally every 6 months or as needed in support of anomaly resolution.

3.2.4.9 Assess Band-to-band Registration

The Assess Band-to-band Registration sub-function provides a numerical evaluation of the accuracy of the registration of each ETM+ band to all other bands within a single all-bands Level 1G image. Assessment is performed on a Level 1G image of high feature content in all bands. Feature selection is conducted with the use of an image display package. Feature mensuration in all bands is performed and a computation of feature location in image space is made. Comparison of image space residuals is made to determine relative band-to-band registration. A significant sample size is used to produce a statistical evaluation point. Assessment data are provided to the Perform Trend Analysis and Generate Reports sub-functions. Assess Band-to-band is performed nominally every 6 months or as needed in support of anomaly resolution.

3.2.4.10 Assess Image to Image Registration

The Assess Image to Image Registration function provides a numerical evaluation of the accuracy of the registration of common bands of temporally distinct ETM+ Level 1G images. Assessment is performed via mensuration of common features in separate Level 1G images covering common terrain. One of the Level 1G iamges is designated as the reference image. The second image has been processed to Level 1G with the use of ground control points identified in the reference image. Registration accuracy is computed using features not used in the Level 1 processing via digital correlation techniques. A significant sample size is used to produce a statistical evaluation point. Assessment data are provided to the Perform Trend Analysis and Generate Reports sub-functions. Assess Image to Image Registration is performed nominally every 6 months or as needed in support of anomaly resolution.

3.2.4.11 Assess Geometric Accuracy

Within the Assess Geometric Accuracy function, an analyst performs visual assessments of Level 1G images to identify linear feature discontinuities and other geometric distortions. Output of this function is provided to Generate Reports for inclusion in image assessment reports.

3.2.4.12 Evaluate 0R Data & Product

The Evaluate 0R Data and Product sub-function includes both visual and electronic examination of the Level 0R data and product for indications of non-satisfactory performance. Evaluation data are provided to the Perform Trend Analysis and Generate

Reports sub-functions. Evaluate 0R Data and Product is performed nominally every week or as needed in support of anomaly resolution.

3.2.4.13 Evaluate Payload Correction Data (PCD)

The Evaluate PCD sub-function inspects and analyzes the quality of the PCD data for the purposes of identifying potential anomalous or erroneous data, as well as to summarize key indicators for longer term trend analysis. In anomalous situations, Evaluate PCD shall be performed for the purpose of isolation and detector of anomaly origins. Evaluation data are provided to the Perform Trend Analysis and Generate Reports sub-functions. Evaluate PCD is performed nominally every 90 days (TBR) or as needed in support of anomaly resolution.

3.2.4.14 Evaluate LPS Quality Data

The Evaluate LPS Quality Data sub-function inspects and analyzes the quality indicator data provided by the LPS to the LPDAAC. Nominally, the data will be reviewed and summarized for the purposes of further trend analysis. In anomalous situations, the LPS quality data will be reviewed as a potential source of system performance degradation. Evaluation data are provided to the Perform Trend Analysis and Generate Reports sub-functions. Evaluate LPS Quality is performed nominally every week or as needed in support of anomaly resolution.

3.2.4.15 Perform Trend Analysis

The Perform Trend Analysis sub-function collects assessment data from each of the Performance Evaluation sub-functions described above, collates the data with previous assessment data, generates time history plots, and analyzes the historical data for evidence of performance trend indicators. Trend analysis results are forwarded to the Generate Reports sub-function. Trend analysis results are generated on a biweekly basis.

3.2.4.16 Generate Reports

The Generate Reports sub-function collects assessment data and trend analysis results from each of the Performance Evaluation sub-functions described above. This function generates standard and customized reports capturing the evaluation and assessment data and summarizing the performance characterizations. Reports are provided to Control Processes and Manage Data function.

3.2.5 <u>Control Processes And Manage Data</u>

The Control Processes and Manage Data function is responsible for the day-to-day management of information in the IAS. Control Processes and Manage Data consists of the IAS hardware and software architecture. Duties of Control Processes and Manage Data include the on-line storage, archival and retrieval of image, product, calibration, evaluation, and performance data. Figure 3.2.5-1 presents the data flow diagram.

3.2.5.1 Control Processes

The Control Processes sub-function is responsible for establishing the connectivity between IAS processes and transfering data among them, the on-line data store and the IAS archive. The Control Processes sub-function manages the data into and out of both the

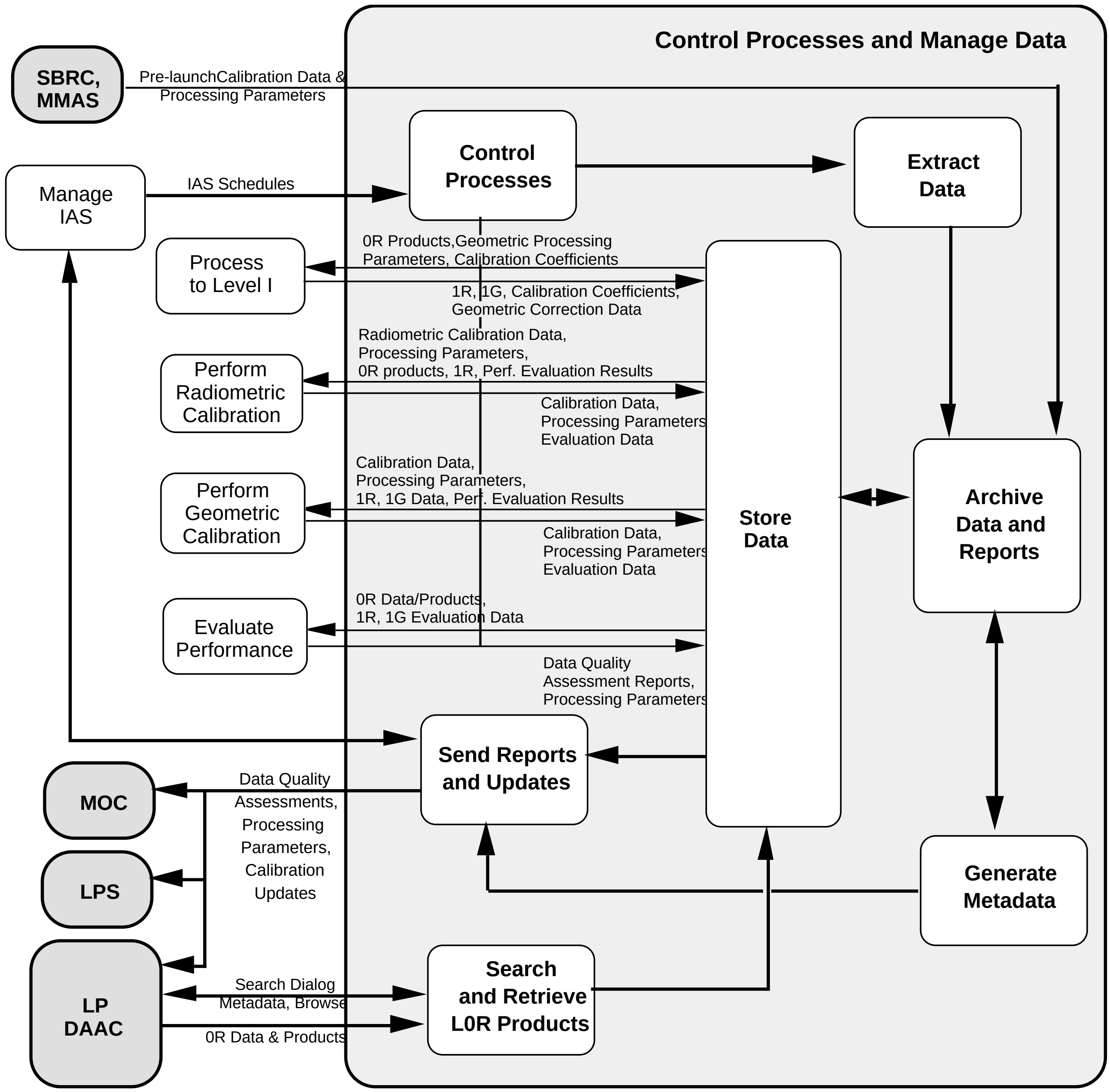

Figure 3.2.5 -1 Control Processes and Manage Data

on-line storage and IAS archive, determining what data items are required for each process and making them accessible to the processes. Data from the archive, required for IAS processing functions will be identified and extracted as a result of determination by the Control Processes sub-function.

3.2.5.2 Store Data

The Store Data sub-function is the on-line storage of data needed for and generated by the other IAS functions. Data determined to require permanent storage have metadata generated for them and are transferred to the IAS archive. Level 0R products ordered from the LPDAAC for calibration and assessment activities will be stored on-line for use by other IAS functions.

3.2.5.3 Generate Metadata

The Generate Metadata sub-function is responsible for establishing and maintaining, for the IAS archive, the metadata for all associated image data and products residing in the IAS archive. Metadata is generated as data on-line is determined to belong in the IAS archive. The Generate Metadata sub-function also creates metadata, for use in the LPDAAC, for the assessments, processing parameters, and calibration updates sent from the IAS to LPDAAC.

3.2.5.4 Extract Data

The Extract Data sub-function is responsible for identifying and extracting data from the the IAS archive required for IAS processing functions. When the Control Processes sub-function requests data and/or products for a process, the Extract Data sub-function identifies the location of the needed data and assures process access to that data in on-line storage.

3.2.5.5 Archive Data and Reports

The Archive Data and Reports sub-function is responsible for establishing and maintaining an IAS archive of all image data and products needed by the IAS to conduct its evaluation of performance, calibration of the vehicle and sensor, assessment of data and product quality, and conduct anomaly investigations. Level 0R data and products, 1R and 1G images and associated image data are archived. Level 0R data redundancy with the LPDAAC archive should be minimized as a goal, with the decision to archive separately in the IAS based upon policy established by the Manage IAS function. Archival of Level 1R and 1G data shall be base upon the Manage IAS policies as well, with the intent being to maintain in the archive all Level 1R and 1G data that are integral to ongoing IAS activities.

Additionally, the Archive Data and Reports sub-subfunction maintainsan IAS archive of all performance related data generated or received by the IAS. This performance data includes pre-launch calibration data from the payload and vehicle, calibration parameters, processing parameters, evaluation data, and reports. The reports to be archived include all reports from the IAS functions, sub-functions, and processes. All performance data shall be time tagged with time of receipt and/or generation, as well as with time of applicability. Time of applicability refers to the time period over which the calibration or processing parameters should be applied, or the time period over which performance assessment report data spans.

3.2.5.6 Send Reports and Updates

After review by the IAS manager, in conjunction with the LSQAT, reports, processing parameters and calibration updates are compiled from the IAS archive and data store. The Generate Metadata sub-function generates the appropriate metadata and the Send Reports and Updates sub-function then forwards the information to the MOC, LPS, and LPDAAC. The reports and assessments are generated by the Performance Evaluation fucntion, and the processing parameter and calibration updates are generated by the other IAS processing functions.

3.2.5.7 Search and Retrieve L0R Products

Search and Retrieve L0R Products is the sub-function in which an IAS operator establishes a search dialog with the LPDAAC in order to view metadata of the LPDAAC contents and selected browse data. Data is searched and characteristics matched for use in calibration activities. Once specific scene data is identified for use in IAS activities, the Search Retrieve L0R Products sub-function is responsible for the ordering and the receipt of data and products from the LPDAAC.

3.2.6 Manage IAS

The Manage IAS function is responsible for the day-to-day management of the IAS. Duties of the Manage IAS function include review of performance related data, interfacing with the other Landsat 7 elements, and planning and scheduling the IAS activities. The Manage IAS function is performed by the IAS manager, in conjunction with the Landsat 7 Science Quality Assurance Team (LSQAT). Day-to-day management is provided by the IAS Manager. Together, they comprise the IAS Management team. Figure 3.2.6-1 presents the data flow diagram.

3.2.6.1 Plan & Schedule IAS Activities

The Plan and Schedule IAS Activities sub-function is responsible for developing and maintaining the schedule of activities performed within the IAS. Duties include the establishment of IAS work rules and policies, identifying need and timing of calibration acquisition requests, generating an IAS internal schedule of activities to maintain a consistent staffing level, coordination of ground site calibration team efforts, and establishing the activities list and schedule needed to accomplish the various IAS responsibilities.

3.2.6.2 Review Reports & Calibration Updates

The Review Reports and Calibration Updates sub-function is responsible for reviewing all reports and calibration updates generated by the IAS functions. The purpose of the review is to establish consistency, veracity, and consequences of the report data and conclusions prior to external IAS release. The review is performed by the IAS Management team. In the case of calibration updates, the Management team shall review the potential update and decide whether the update is required for performance and quality improvements, or whether the update is not of a significant nature to require external release.

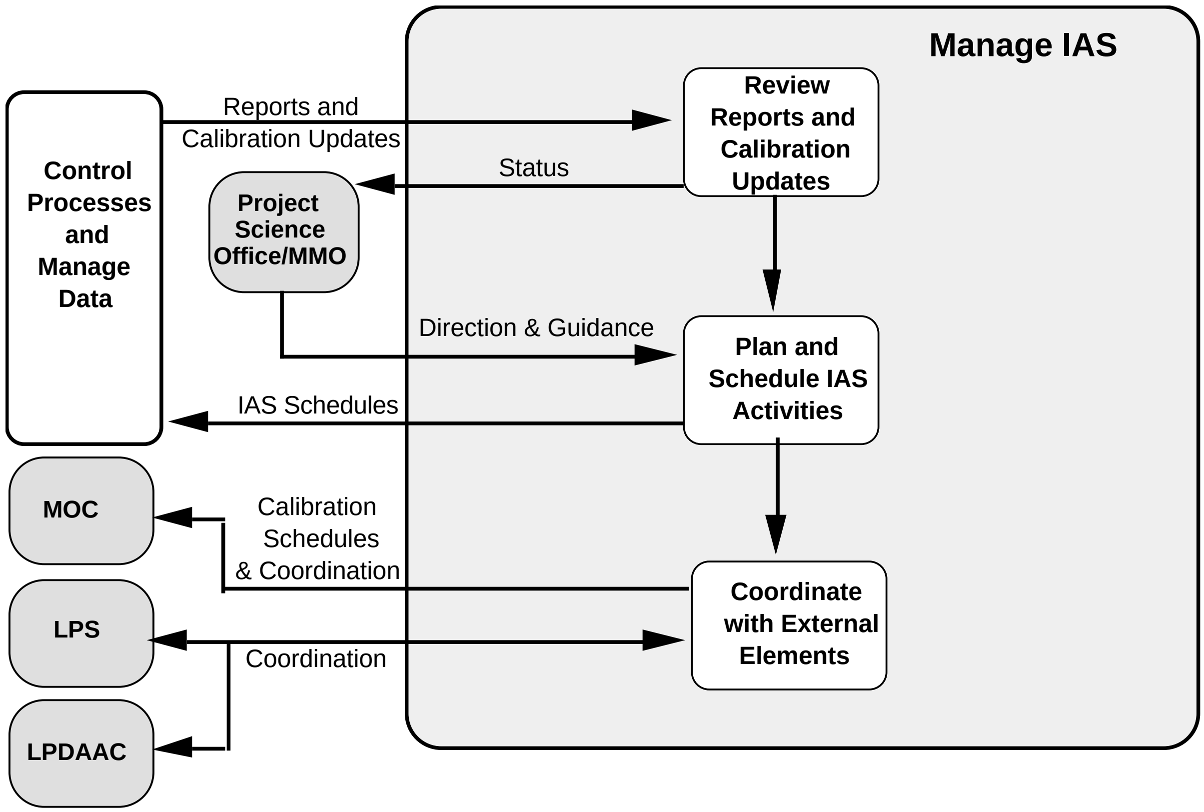

Figure 3.2.6 -1 Manage IAS Data Flow Diagram

3.2.6.3 Coordinate with External Elements

The Coordinate with External Elements sub-function is responsible for interfacing with the MOC for the planning and scheduling of IAS required data collections. These data collections are nominally conveyed as scheduled calibration activities, though coordination for other acquisition requests may also be needed. Additionally, this sub-function coordinates all calibration updates with the MOC for their subsequent forwarding to the IGSs and maintains cognizance of MOC engineering activities. Upon the release of any IAS report or calibration update to MOC, LPS, or LPDAAC that requires or recommends action by an element external to the IAS, the IAS Management team shall notify appropriate external element management of the nature of the action needed.

SECTION 4
OPERATIONAL SCENARIOS

4.1 SCENARIO OVERVIEW

The scenarios described below are designed to provide insight into the operational activities that will be conducted by the IAS in support of mission success. They will describe the sequence of events that constitute several of the major functional activities performed by the IAS in its performance and assessment role. The events depicted include pre-launch test support activities, a radiometric calibration, a geometric calibration, typical performance evaluation activities, and an anomaly investigation.

4.2 PRE-LAUNCH TEST SUPPORT

TBD

4.3 RADIOMETRIC CALIBRATION

Radiometric calibration is performed to establish and maintain baseline performance capability for radiometric accuracy and quality. Radiometric calibration is necessary to establish the proper relationship between detector output and radiance levels. Pre-launch calibration provides a characterization of the detectors, but cannot determine the post-launch calibration curves. Calibration activities for radiometry include use of all the calibration devices present on the Landsat 7 vehicle. These include the internal shutter, the full aperture solar calibrator, and the partial aperture solar calibrator. Additionally, ground look calibrations will also be performed. Combining these multiple calibration approaches will be performed by an optimal estimator. This will establish the basis for achieving the absolute radiometric accuracies. External equalization may be performed as needed to establish relative radiometric performance baselines.

Prior to launch, the IAS Management team in conjunction with the LSQAT will identify appropriate ground truth locations to support the ground look calibration exercises. Site identification and pre-coordination of the ground look calibration collection and with ground truth team is needed. Figure 4.3-1 depicts potential ground truth sites.

Upon completion of the outgassing of the primary focal plane (at launch plus 4 days), radiometric calibration collections can commence. Nominal plans call for partial aperture solar calibrator (PASC) collections once per day, full aperture solar calibrator (FASC) collections once every 5-6 weeks (minimum of 3 times before IOC), and ground look calibration collections every 2-6 months (minimum of 3 times before IOC). During early orbit checkout, calibration collections will be more frequent, up to every orbit for the PASC and twice per week for the FASC, tapering to nominal collection frequencies and procedures as confidence is gained in the stability of the calibration coefficients. Internal shutter data are available for each ETM+ scan.

The IAS Management team generates calibration schedules outlining the desired collections and forwards them to the MOC. Outgassing for bands 1-4, and 8 (pan) is scheduled to complete at launch plus 4 days (L+4), so collections can begin for these bands. Completion of outgassing for the cold focal plane is scheduled for L+30, at which point, the subsequent calibration collections will provide data for all bands.

The MOC shall plan and schedule the WRS collections according to the parameters of the calibration schedule. The vehicle shall collect the scenes and transmit the wideband data to EDC. The IAS Management team will track the status of the collection by coordination with the MOC. Captured by the LGS, processed to Level 0R by the LPS, and archived by the LPDAAC within 24 hours after receipt, the calibration image data and supporting data becomes available for browse to the IAS.

Figure 4.3-1 Potential Radiometric Calibration Ground Look Sites

For the ground look calibration collections, the IAS staff will browse the collections, determine which are suitably clear for the purposes of calibration and request the data from the LPDAAC. Availability for delivery shall occur within 24 hours. For full and partial aperture collections, the data will be requested when available.

The IAS Management will plan and schedule the calibration activities within the IAS. Upon receipt of the requested data, level 0R data, 0R products, and metadata will be archived in the IAS. For the partial aperture collections, an IAS work order will be issued to execute the Process Partial Aperture function. This function will produce a detector response / input radiance calibration point per collection per detector, captured in a calibration report. This function may be executed daily for each collection, or less frequently on several collections. Similarly for the full aperture collections, work orders will be generated for the execution of the Process Full Aperture function. Resulting calibration curves are documented in the calibration report. Upon the successful collection of a ground look calibration target, the IAS shall obtain ground truth data from the ground site team and archive the data in the IAS archive. The ground look collection shall be processed to Level 1R. Using the 1R image, the Process Ground Look function shall identify the target area and extract the appropriate pixel data from the 0R product. Response/radiance curves will be generated by this function.

During this period of calibration activity, the IAS Management team shall be reviewing the calibration data. At regular intervals work orders for the execution of the Perform Optimal Estimation function shall be issued (Timing dependent upon the completion of the calibration activities outlined above, as well as the existence of significant amounts of new input. The optimal estimation will be executed after each ground look and full aperture calibration exercise). Calibration data from the above processing will be input to the function. Pre-launch calibration data shall serve as the initial best estimate for the detector gains and biases. Calibration updates output from the optimal estimator shall be captured in a calibration report and reviewed by the management team. At this point, the latest full aperture collection will be re-processed to Level 1R utilizing the calibration updates. The 1R image will be input to the Perform Equalization function. Final detector gains are output and forwarded to the IAS management for review. The calibration update is incorporated into the baseline processing parameter file for radiometric correction. The updates are also forwarded to the LPDAAC, with the IAS Management team directing release of the reports and notifying the appropriate Landsat elements and Project Management office of the change to the baseline. The IAS updates its own parameter database. The LPDAAC makes the calibration updates available to users by including the updated parameters in all future user order requests.

4.4 GEOMETRIC CALIBRATION

Geometric calibration is performed to establish and maintain baseline performance capability for geometric accuracy and quality. The initial geometric calibration exercises are needed to remove any biases associated with launch induced shifts in the alignment, focal plane geometry, mirror profiles and/or changes to the detector timing. Calibration activities shall be performed as soon as possible after the completion of payload outgassing.

Prior to launch, the IAS Management team in conjunction with the LSQAT identifies target WRS scene as good candidates for geometric calibration collection. This selection is based upon availability of ground truth data (geodetic latitude, longitude, and height), as well as scene content (significant sample of features present to support statistical calibration of geometric parameters), and seasonal/regional weather patterns consistent with high probability of clear collection in the immediate post-launch period.

The types of scenes needed for geometric calibration are related to the calibration methods anticipated for use. For determination of detector delay profiles, scenes of high frequency spatial content are needed. Urban metropolitan areas in the continental United States (CONUS) would support the needs of the detector delay calibration. For band-to-band calibration, scenes containing features with distinguishably sharp edges (and hence, good digital correlation candidates) such as bridges, airport runways, major road intersections, and large buildings surrounded by open space or large parking lots would suffice. Again, metropolitan areas may support this, as would military or government installations. For detector delay and band-to-band calibration, ground truth data are not required, so an abundance of candidate WRS scenes should be readily available. For calibration of scan mirror profiles, a large accurate control grid is necessary, such as a rural road network. Highly accurate ground control information is desired to support calibration of relative small uncertainties in the scan mirror profile.

For alignment calibration, WRS scenes with ground truth targets are required. In fact, given the large magnitude of systematic errors (ephemeris, attitude, alignment), a significant amount of clear image collection is needed to support the error reduction process in the calibration activity. Again, given the availability of USGS ground truth data, the CONUS presents a wealth of ground truth targets of sufficient accuracy. A limiting factor of CONUS collection, however, will be the need to analyze (and calibrate) both alignment and band-to-band registration variability over the length of a descending pass. Additional ground truth data over a range of latitude and longitude will be needed to address this potential variability.

Figure 4.4-1 depicts a typical WRS target distribution within the CONUS to support geometric calibration.

Figure 4.4-1 CONUS Geometric Calibration targets (Notional)

Having identified the desired WRS scenes, the IAS Management team generates a calibration schedule outlining the desired collections and forwards them to the MOC. Outgassing for bands 1-4, and 8 (pan) is scheduled to complete at launch plus 4 days (L+4), so collections can begin for alignment, detector delay, and band-to-band . Alignment calibration will utilize pan band only. Band-to-band calibration will be limited to within the primary focal plane. Detector delay calibration will be limited to bands 1-4 and 8. Completion of outgassing for the cold focal plane is scheduled for L+30, at which point, the remaining detector delay calibrations can be initiated. Band-to-band registration within the cold focal plane and between focal planes can also be started.

The MOC shall plan and schedule the WRS collections according to the parameters of the Special Acquisition Request. The vehicle shall collect the scenes and transmit the wideband data to EDC. The IAS Management team will track the status of the collection by coordination with the MOC. Captured by the LGS, processed to Level 0R by the LPS, and archived by the LPDAAC within 24 hours after receipt, the calibration image data and supporting data becomes available for browse to the IAS.

The IAS staff will browse the collections, determine which are suitably clear for the purposes of calibration and request the data from the LPDAAC. Availability for delivery shall occur within 24 hours.

The IAS Management will plan and schedule the calibration activities within the IAS. Upon receipt of the requested data. Level 0R data, 0R products, and metadata will be archived in the IAS. An IAS work order requesting processing to Level 1G is issued. Utilizing the pre-launch calibration and processing parameters, the detector delay collections will be processed to Level 1G. (Note : radiometric correction will most likely be uncalibrated in the early stages of post-launch activity. This will not affect the accuracy of the detector delay calibration. Level 1G processing will include resampling with corrections applied only in the along scan direction.) A second work order will direct that the Level 1G image be processed by the Cross Scan Calibration function. Candidate updates to the detector delay profiles will be developed and captured in the calibration reports. Level 1G processing will be repeated with the candidate updated detector delay parameters. A performance evaluation of the calibrated 1G image will be ordered , with the results captured in an evaluation/assessment report. The calibration and evaluation reports will be reviewed by the IAS Management team. If the results are deemed to be acceptable, the calibration update is incorporated into the baseline processing parameter file (If results are not acceptable, the calibration process will be repeated with a different WRS scene collection). The updates are also forwarded to the LPDAAC, with the IAS Management team directing release of the reports and notifying the appropriate Landsat elements and Project Management office of the change to the baseline. The IAS updates its own parameter database. The LPDAAC makes the calibration updates available to users by utilizing the updated parameters in all future user order requests.

Upon calibration of the detector delay profiles, the IAS shall issue a work order for the processing of the band-to-band calibration collections to Level 1G. Utilizing the pre-launch field angle data, the collections are processed to Level 1G. A second work order will direct that the Band-to-band calibration function be executed. Candidate updates to field angle database will be developed and captured in the calibration reports (The initial calibration will deal with the primary focal plane bands. A second calibration at completion of cold focal plane outgassing will be conducted for bands 5,6, and 7). Level 1G processing will be repeated with the candidate field angle updates and a band-to-band registration performance evaluation will be conducted, with results documented in the evaluation report. Review of the reports by the IAS Management team will determine the acceptability of the proposed update. The IAS updates its own parameter database. Updates are forwarded to the LPDAAC, reports are released, and the IAS Management team communicates the change notice. Updates are now part of the baseline and are available to the users through the LPDAAC.

With the completion of the detector delay and band-to-band calibration (primary focal plane only), the alignment calibration activities may commence. The IAS will direct the processing to Level 1G of the pan band for each of the alignment collections (By this time, multiple collections should be available). The Alignment Calibration function is then started. Measurement data are generated for input to the Alignment Model. If sufficient data are available (estimated 12 scenes collected over separate revs to achieve specification levels of performance), the alignment update is determined, and a calibration report is generated. If an insufficient amount of data to achieve spec are currently available, a preliminary alignment update may be generated until sufficient collection may be obtained. Level 1G processing is repeated with the updated alignment angles. Performance Evaluation (in this case, a geodetic accuracy evaluation) is conducted and an evaluation report is generated. The IAS Management team reviews the reports, approves the update, releases the reports, and directs the updated parameters to be forwarded to the LPDAAC. IAS processing databases are updated. Users now have available to them a completely calibrated set of geometric parameters to achieve specification levels of performance.

4.5 PERFORMANCE EVALUATION

Performance evaluation covers a broad range of topics designed to ensure that the Landsat 7 system is producing accurate and high quality data. Regular and systematic review of the data is planned to detect any anomalies that may occur. Additionally, the continual evaluation of data provides the input to trend analysis which may reveal lower frequency changes in the output product as well as indicate that calibration activities may need to be initiated. The input to the evaluation product is the 0R data and products produced by the LPS and archived in the LPDAAC, and the products of the IAS itself, Level 1R and 1G. Evaluation data, produced by the operational processes, both internal and external to the IAS, are also part of the evaluation process.

Performance evaluation can be discussed in terms of three major activities, each of which contains multiple evaluation steps. These include data processing quality which reviews the LPS processing quality indicators, the 0R supporting data (PCD, ancillary data, narrow band telemetry), and all levels of images for image artifact detection, geometric quality evaluation in which the Level 1G image generated by the IAS is evaluated, and radiometric quality evaluation which evaluates Level 0R data and products and 1R data.

4.5.1 Data Processing Quality

Data processing quality evaluations refer to those activities designed to assess and review the data that are received by the IAS and the processes that generated the data. The LPDAAC archive will contain the Payload Correction Data (PCD) and image data processed to 0R by the LPS, as well as LPS quality data generated by the LPS processing itself. The IAS shall request and archive selected quantities of these data and perform a general review for the purposes of identifying potential performance impacting trends or indications of systematic errors in the data. Evaluation reports will be written and reviewed, and archived. As needed, the IAS management team will notify the appropriate Landsat 7 elements upon the detection of any non-nominal assessments.

One Level 0R scene product is ordered once per day (TBR) specifically for the purpose of assessing data processing quality. The metadata and cloud cover assessment are checked for accuracy and completeness and the browse data is assessed. The processing parameters supplied are checked that they are the appropriate and most current, and then used to generate a systematically corrected 1G image. The 1G image is also visually inspected for radiometric artifacts and geometric distortions.

4.5.2 Geometric Quality

At a minimum frequency of every 6 months, a formal geometric quality evaluation will be conducted. The IAS shall generate a special acquisition request for a WRS collection of a target area which contains a high volume of accurately known ground features (geodetic ground control points). The target area shall be collected twice.

The MOC shall plan and schedule the WRS collections according to the parameters of the Special Acquisition Request. The vehicle shall collect the scenes and transmit the wideband data to EDC. The IAS Management team will track the status of the collections by coordination with the MOC. Captured by the LGS, processed to Level 0R by the LPS, and archived by the LPDAAC within 24 hours after receipt, the image data and supporting data become available for browse to the IAS.

The IAS staff will browse the collections, determine suitability for the purposes of evaluation and request the data from the LPDAAC. Availability for delivery shall occur within 24 hours.

The IAS Management will plan and schedule the evaluation activities within the IAS. Upon receipt of the requested data. Level 0R data, 0R products, and metadata will be archived in the IAS. An IAS work order requesting processing to Level 1G is issued. The work order will request Level 1G processing utilizing systematic correction only, precision correction, and terrain correction. The resampled 1G images are then input to the Performance Evaluation - Assess Geodetic Accuracy function. Utilizing the geodetic ground control points, geodetic accuracy assessments will be made for each of the Level 1G processing options. The IAS management team shall review the assessment data. Within specification assessments shall be documented in an assessment report. Out of specification assessments shall initiate an anomaly investigation. Similar assessments shall be conducted for band-to-band and temporal registration accuracy requirements. For band-to-band , features shall be selected in a reference band (pan) and all other bands. Direct measurements of misregistration between bands are made. For temporal, features shall be selected in all bands of one of the two collections designated as the reference interval. Direct measurements of the misregistration between bands of the separate images shall be performed. Again, assessments within specification shall be documented in an assessment report. Out of specification results are documented as well with an anomaly investigation to follow.

All assessment results are also evaluated in comparison to previous assessment as part of the trend analysis routinely performed by the performance evaluation function. Assessment results that constitute a significant change from the previous evaluation may warrant additional evaluation.

4.5.3 Radiometric Quality

Radiometric quality evaluation is performed to assess radiometric accuracy, determine noise levels, quantify streaking and banding, and to characterize detector response.

The IAS shall survey first the IAS archive, then the LPDAAC archive holdings for appropriate Level 0R data and products for the purposes of radiometric quality evaluation. For MTF evaluation, an image containing long, high contrast, straight edge features (bridges, highways) is needed. For radiometric accuracy, the latest ground look calibration imagery shall be utilized. For assessment of detector outage, SNR, banding, streaking, correlated noise, and coherent noise, the latest full aperture solar calibration data will be used. Additionally, imagery with flat uniform responses may be employed. For scan droop and bright target recovery assessments, uniform ground scenes with some cloud cover will be needed. The cloud cover will provide indications of detector response to saturation and subsequent response upon return to ground radiance levels.

Imagery and data obtained from the LPDAAC will be stored in the IAS archive. Assessment activities for all of the diagnostics listed above will be initiated. Comparison of the assessment results versus specification will be made. Results will be captured on evaluation reports. Evaluation data will be analyzed along with previous assessments by the trend analysis function. The IAS management team will review the evaluation and trending reports and determine requirement satisfaction. Indications of negative performance trends or out of spec performance may lead to additional evaluation or declaration of an anomaly. Evaluation and trending reports will be archived as well as submitted to the Project Management Office.

4.6 ANOMALY INVESTIGATION

The IAS will play a role in anomaly investigations as needed to support the performance and quality objectives of the Landsat 7 system. A variety of potential anomalies can be described as scenarios. The IAS response to an anomaly declaration will, of course, vary depending upon the nature and severity of the anomaly. Generically, the IAS can be anticipated to respond to three types of anomalies : user identified anomalies, anomalies detected internal to the Landsat 7 system, and anomalies detected internally to the IAS. Scenarios addressing these anomaly categories are described below

4.6.1 User Identified Anomalies

The Landsat 7 system provides 0R data and products and metadata to the user community. Subsequent data processing by the users is performed pursuant to their individual needs. It can be anticipated that erroneous conditions may arise during user processing that may not have been identified by the Landsat 7 system.

An user will notify the Landsat 7 system of potential problems with a specific set of Landsat data via its external interface agents and be brought to the attention of the Flight Operations Manager (FOM). In the event of a user problem with the performance and quality of the data provided, the FOM will include the IAS as representatives on the anomaly team. The IAS will support the anomaly investigation by initiating a performance evaluation on the specific set of data identified by the user. The IAS shall request the data from the LPDAAC and store it in the IAS archive. Should the data be non-resident in the LPDAAC or there is reason to believe that the problem is specific to the user version of the data, the IAS will request that the user interfacing agents attempt to acquire the data from the user. Depending on the nature of the problem, the IAS management team will direct the appropriate performance assessment and evaluation activities. If the user has identified a problem that may be associated with his own processing techniques, the IAS may activate its corresponding processing functions in an effort to isolate the problem. This would include processing the data to Level 1R and 1G as necessary. Inability to recreate the user problem via IAS processing would lead the IAS to the conclusion that the problem is user specific. The IAS management team reports the results of their finding to the anomaly team director. Response to the user would include an IAS generated report indicating the processing approaches employed by the IAS in their successful processing of the user's data. Should the IAS investigation result in concurrence with the user identified problem, additional anomaly isolation activities would result. At this time, the anomaly will have been isolated to be within the Landsat 7 system itself. Internal system anomaly scenarios are described below.

4.6.2 Landsat 7 System Anomalies

When an anomaly is declared within the Landsat 7 system, an anomaly investigation team is formed under the direction of the Flight Operations Manager (FOM). Depending on the nature of the anomaly, various elements of the Landsat 7 system may be included on the anomaly investigation team. Due to the nature of its charter, the IAS will likely be included on most anomaly investigations. The first step in anomaly investigation shall be an examination of the timeline of events prior to the detection of the anomaly. With its functionality to perform image assessment and evaluate performance and quality factors, the IAS will support the anomaly investigation by evaluating the anomaly data available to it. These evaluation steps are described in Section 4.5. Assuming that the anomaly was detected external to the IAS (IAS internal anomaly investigation are discussed in Section 4.6.3), the IAS assists the anomaly isolation process by reviewing any pertinent quality and performance data within the immediate time period of the anomaly. Additional data may be requested from the LPDAAC of a historical nature to establish the initial instance of the anomaly. The IAS focus will be determined by the nature of the anomaly. It may play a role in recreation of the anomaly events, assess the potential performance impacts of the anomaly characteristics, or perform trend analysis to provide insight into potential anomaly causal factors.

Once the anomaly has been isolated, the IAS plays a role in the identification of alternative resolution strategies as well as the evaluation with respect to performance and quality of product of those alternatives. The IAS may identify workarounds until a long term solution can be implemented and demonstrate system capability under those workarounds. If image processing solutions are proposed, the IAS will provide leadership in testing and evaluating those solutions.

4.6.3 Internal IAS Anomalies

The last type of anomaly that may be encountered is IAS self-detected anomalies. These anomalies may result from the processing and evaluation activities conducted by the IAS. Should system performance degradation or out of spec performance be observed, the IAS review process will first look internally to decide if IAS activity if responsible. The IAS will initiate an evaluation of the input data it receives from the LPDAAC. 0R data and products are evaluated. PCD and LPS quality data are reviewed for potential underlying anomaly causes. Systematic anomaly isolation is initiated for all of the IAS activities performed prior to anomaly detection. Internal evaluation data from the IAS level 1 processing is reviewed. Should the internal anomaly investigation result in no clear identification of an IAS problem, the IAS management team shall identify the problem to the Flight Operations Manager, at whose discretion a system anomaly may be declared. If the evidence suggests that the anomaly is isolated internal to the IAS, the IAS Manager may declare an IAS anomaly. An anomaly team under the direction of the IAS Manager (or designee) will be formed. As needed, IAS external elements may be requested to participate in the anomaly investigation. The anomaly team shall remain in place until a resolution implementation plan has been developed. Upon resolution, the IAS Manager informs the Flight Operations Manager of return to operational capability.

5.0 NOTES

5.1 GLOSSARY

0R: The stage in the processing prior to radiometric or geometric correction of an image and after the pixels have been placed in detector spatial order.

OR Product: Products distributed by the LPDAAC to include all bands; 0R image data, browse data, metadata, radiometric calibration data, radiometric calibration coefficients, PCD, geometric processing parameters, and mirror scan correction data.

1R: The stage in the processing after radiometric correction has been applied to an image.

1G: The final stage in the processing after radiometric and geometric corrections have been applied to the image data.

Ancillary Data: Spacecraft attitude and ephemeris, radiometric correction coefficients, geometric processing parameters, and image quality statistics.

Archive: Permanent, off-line storage of data, software and documentation.

ASPAM: A model which creates a report on meteorologic conditions including such items as pressure, temperature and water vapor content as a function of altitiude, at a particular time and place, derived from empirical and interpolated data by USAFETAC (more than 48 hours after the fact).

Bright Target Recovery: Also known as memory effect

Calibration Activities: Recalculating of the radiometric correction coefficients or geometric processing parameters.

Data Storage: On-line storage of data accessible to the various functions within the IAS.

Equivalent At-Aperature Radiance: Estimated radiance from other than full aperature radiance.

Entrance Aperature Radiance: Actual full aperature radiance.

ETM+ Equivalent Scene:
Level 0R Image Data (6320+225) x 5984 x 6 + (12640+450) x 11968) +
((3160+113) x 2992 x 2) = .41 GB
Level 1G, non-rotated, resampled to 25m (except Pan to 12.5m)
220km x 170km/(.025km/pix)^2 x 2bytes/pix x 7 bands +
220km x 170km/(.0125km/pix)^2 x 2bytes/pix = 1.3 GB

Geometric Accuracy: The accuracy with which the image data matches spatial relationships as they are on the earth.

Geometric Artifacts: Assessment of geometric artifacts (or assessment of geometric accuracy) includes visual assessment of discontinuities of linear features, scale distortion, panoramic distortion, and any other distortions.

Geometric Processing Parameters: Orbit parameters, instrument and alignment parameters, focal plane band locations, scan mirror profile coefficients (along scan and across scan), odd detector sample shifts, alignment matricies, ADS calibration parameters, gyro calibration parameters, along scan focal plane detector offsets, temperature calibration coefficients, inoperable modes,resampling coefficients, MTF coefficients and MTF compensation.
* Need to include parameters for the thermal band also.*
* Include also the short term file parameters such as Pole Wander data, UT1, UT2, and detector status*.

Ground Look Calibration: The process of radiometrically calibrating the payload, on-orbit, by comparing payload readings to estimated radiances reaching the payload from ground scenes using on-site ground and atmospheric measurements.

Ground Measurement Data: Also known as ground truth data.
- Normal image data of ground truth site collected in low gain mode.

- In-band target radiance measurements coincident with the Landsat 7 overpass.
- In-band irradiance measurements of the ground.
- Temperatures of the water at selected depths from the surface to one meter below the surface (for band 6 calibration)
- Air temperature and wind speed and direction just above the water temperature probes (for band 6 calibration).
- Atmospheric measurements to include: Pressure, temperature and relative humidity/water vapor density as a function of altitude as reported by radiosondes launched within on hour prior to the over pass of Landsat 7; Surface level pressure, temperature, and relative humididty/water vapor density; Surface level aerosol measurements and a ground visibility measurement within one half hour of the overpass; And Lidar measurements of water vapor density as a function of altitude within five minutes of the overpass.
- Full ASPAM report from USAFETAC for comparison.

Radiometric Image Artifacts: Streaking, banding, scan line droop, bright target recovery response (aka memory effect), coherent and correlated noise.

In-Orbit Checkout (IOC): The 45 day period specified after launch during which spacecraft and sensor systems are activated, checked out, outgassed, and initially calibrated.

Initial Operational Capability (IOC): Milestone after satellite initialization and checkout wherein operations are transferred from the developers (NASA) to the system operators (NOAA).

Inoperable Detectors: Detectors meeting the following criteria shall be declared inoperable. a) The quantized digital number (DN) is below 50% of the full scale DN value when a detector is exposed to the ETM+ minimum satuation levels. b) The quantized digital number (DN) reaches full scale while the input radiance is at or below 0.70 times the ETM+ minimum saturation levels. orc) The signal-to-noise ratio (SNR) performance degrades to 50% or below the specified ETM+ minimum SNR values.

Level 1G Data: Includes both 1G imagery and geometric correction data.

Level 1G Imagery: Image data which has been geometrically corrected .

Pre-launch Data:

Radiometric Calibration Coefficients:

Radiometric Calibration Data:

5.2 ACRONYMS

ACCA	Automated Cloud Cover Assessment
ASPAM	Atmospheric Slant Path Analysis Model
BRDF	Bi-directional Reflectance Distribution Function
CONUS	Continental United States/Contiguous United States
DEM	Digital Elevation Model
EDC	EROS Data Center
EROS	Earth Resources Observation System
ETM	Enhanced Thematic Mapper
FASC	Full Aperture Solar Calibrator
FHSERR	First Half Scan Error
GCP	Ground Control Point
GLC	Ground Look Calibration
GSFC	Goddard Space Flight Center
IAS	Image Assessment System
IGS	International Ground Station
IOC	In-Orbit Check Out or Initial Operational Capability
LGS	Landsat 7 Ground Station
LOS	Line-of-Sight
LPS	Landsat 7 Processing System
LPDAAC	Land Processes Distributed Active Archive Center
LSQAT	Landsat Quality Assurance Team
MMO	Mission Management Office
MOC	Mission Operations Center
MSCD	Mirror Scan Correction Data
MTF	Modulation Transfer Function
NBR	Navigation Base Reference
PASC	Partial Aperture Solar Calibrator
PCD	Payload Correction Data
PSO	Project Science Office
SBRC	Santa Barbara Research Center; Division, Hughes Aircraft
SHSERR	Second Half Scan Error
USAFETAC	United States Air Force Environmental Technical Applications Center
WRS	Worldwide Reference System